

Oral Health in Diabetes (OHDM): A Validated Tool to Measure Risk Beliefs and Awareness of Potential Complications

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Abstract

Background

People with diabetes are at an increased risk of developing oral health complications, including periodontal disease and dental caries. Despite this heightened risk, perceptions and beliefs about risk and awareness of potential complications remain suboptimal amongst this group. Existing measures used to evaluate these drivers of oral health in adults with diabetes are limited in their scope and of unknown validity. Therefore, the aim of the present study was to develop and validate a new Diabetes Specific Oral Health scale (OHDM) to measure oral health factors in people living with diabetes.

Methods

A questionnaire was created based on existing measures and insights from relevant published literature, and refined in collaboration with dental professionals, scale development experts and with input from people with lived experience of diabetes. Three sets of data were collected from UK dwelling adults (18y+), living with diabetes (Type 1 or 2) via an online panel and subject to Parallel and Exploratory Factor Analysis (EFA) ($n = 328$), Confirmatory Factor Analysis (CFA) ($n = 352$) and test-retest reliability ($n = 37$).

Results

A 23-item scale was initially developed. Following parallel analysis and EFA a two-factor model (Oral Beliefs, Oral Complications) was deemed best fit. Five factor loadings were not significant and subsequently removed, resulting in an 18-item scale. All other loadings were significant and positive (0.5–0.72). CFA was conducted, confirming the two-factor model as a good fit (Tucker-Lewis Index = 0.995, Root Mean Square Error of Approximation = 0.017, Standardized Root Mean Square Residual = 0.073). Reliability of the two subscales was good: oral beliefs ($\omega_T = 0.91$), oral complications ($\omega_T = 0.84$).

Conclusions

The OHDM provides a valid research tool for measuring oral health complications and related beliefs in those living with diabetes. Future studies should seek to test the performance of this scale in different groups such as adolescents and those with gestational diabetes and explore its utility for informing targeted oral health education and intervention development.

Clinical trial number: not applicable

Background

Diabetes Mellitus (DM) is an important yet under recognised risk factor of oral health disease (1). People living with DM, both Type 1 Diabetes Mellitus (T1DM) and Type 2 Diabetes Mellitus (T2DM), are at an increased risk of developing oral complications such as gingivitis (inflammation of the gums – early stage of gum disease), periodontitis (advanced gum disease) and other bacterial infections such as dental caries or thrush (2). These DM-related health outcomes are less known and/or understood (3) than others such as neuropathy (nerve disease), retinopathy (eye disease), and nephropathy (kidney disease).

DM can also affect oral health in more indirect ways as it influences immune function and wound healing, making individuals more susceptible to infections and complicating recovery from oral diseases (4). Additionally, people diagnosed with DM are more likely to suffer from other systemic conditions such as (but not limited to) heart disease and hypertension (5). Living with such conditions is known to affect oral health for several reasons, including the increased use of prescription drugs which can vastly change the oral microbiome, leading to several oral complications

such as xerostomia (dry mouth) (6). The relationship between DM and oral health is thus quite complex. It is also thought to be bidirectional, whereby gum diseases such as gingivitis and periodontitis can lead to problems with glycaemic control which is fundamental to DM management and significantly impacts the development and progression of DM-related complications (7, 8). It has also been shown in adults with DM that those with adequate oral health behaviours have better HbA1c (blood sugar) levels than those with poor oral hygiene (9).

Research suggests that people with DM have deficiencies in their specific oral health knowledge (10) and that this may be due to lack of communication between medical and dental professionals and their patients with DM (3, 11). In a qualitative study conducted by the University of Warwick, researchers carried out telephone interviews with 20 adults (mean age 60.8yrs, range 40–82yrs) living with DM in the UK. Overall, there was a lack of awareness from participants of the link between DM and oral health, and participants reported feeling that more information and advice from both dentists and GPs (General Practitioners) regarding this link was needed. However, as GP surgeries seemed to be the main source for DM care (in the UK), participants stated a preference for more oral health discussions from GPs and/or nurses (12). Insufficient oral health education, potentially due to this falling between the gaps in treatment between healthcare services, could be leading to inadequate dental hygiene routines and greater prevalence of subsequent oral complications in people with DM (13).

To inform interventions to address these issues and allocate patients appropriately to improve health outcomes in this population, it is critical that healthcare professionals are able to effectively measure the oral health behaviours and beliefs in people with DM.

However, there is currently no appropriate measurement scale for researchers or clinicians to support understanding of the oral health behaviours and beliefs of people living with DM. Instead, studies have used general oral health questionnaires/scales, but these have notable limitations for this purpose.

The first limitation relates to the inadequate scope and coverage. An example of an existing method can be illustrated by a study focusing on the socioeconomic perspective of oral health and T2DM, in which participants were solely asked to 'assess the overall health condition' of their teeth and gums (14). This question alone is vague, respondents may focus solely on aesthetic aspects, and it fails to collect sufficient data to measure oral health related outcomes. Another study explored parents' responses regarding the oral health behaviours of their children (2–6 yrs) (15). Questions asked during this study referred to the age the child started brushing their teeth and who brushes the child's teeth (child, adult, or both). These items are specific to those without full autonomy over their own health behaviours. Additional questions include the number of times the child has missed preschool, daycare or school because of dental problems or dental treatments. This measure is therefore clearly not applicable for an adult population.

Another scale was developed in the US (United States) (16) and is referred to here as DM-OH. Researchers developed a 7-item oral health knowledge questionnaire specifically for people with DM. However, internal reliability analyses were found to be below acceptable ($\omega_t = 0.69$). Additionally, the scale is problematic as it contains items worded in a positive direction, to elicit a positive ('Correct') response. For example, 'People with diabetes are more likely to have infection in their mouth' (16). The items phrased in this way may imply a specific answer which introduces bias to the dataset and shifts the distribution of responses, therefore skewing the results. Leading questions also fail to accurately address the research question as they measure what the question suggests rather than what the respondent believes.

A second limitation concerns both the validity and reliability of the data. In 1992, a UK study measured the oral health status and behaviours of people living with DM ($n = 642$) and compared their results to data collected in a national survey (17). Several in-person oral examinations conducted over time were used to measure oral health status, which were then compared to data on oral health behaviours from the UK Adult Dental Health Survey (18). These questions relate to oral discomfort, oral complications experienced, oral hygiene behaviours and the importance of oral health (for

the full questionnaire see (17)) but no validity or reliability scores are available for this measure. This reduces the reproducibility of this scale and the certainty that what is set out to be measured is being measured.

Another, similar study regarding oral health awareness of people with DM used items relating to oral hygiene behaviours, with particular focus on participants' experience with dentists (19). Items such as 'Should dentists be involved in diabetes screening?' and 'If dentists did offer screening, would you be willing to pay?' were included as well as more general oral health behaviour questions (such as 'frequency of brushing'). Within this publication, there is no discussion of statistical analysis being carried out on the developed scale and no changes were made after a pilot, suggesting it has not been validated.

A third study included the development of a questionnaire to assess diet and behavioural habits related to oral health (20). This questionnaire was tested on a small sample of only five respondents, despite consisting of a substantial 196 items. A limitation noted within the publication is that it was not validated according to standard procedures. Furthermore, the finalised version is only available in Norwegian, which restricts its accessibility and broader applicability.

A third limitation concerns the variation in research aims across existing tools. For example, the Oral Health Values Scale developed by Edwards et al., (21) was designed to assess the importance individuals place on oral-health-related behaviours and the priority they assign to their oral health. In contrast, the shorter oral health impact profile scale (OHIP-14) focuses on people's perceptions of how oral health conditions affect their overall quality of life (22). Although both instruments are widely used, they were not developed for people with DM and therefore, capture only general oral health impact and quality of life, rather than the specific oral health beliefs and behaviours relevant to populations with DM.

The need for an oral health scale to be specifically tailored towards people with DM and not to the wider public is due to their drastic change in lifestyle once diagnosed as well as their increased risk of oral complications. For example, monitoring of blood glucose levels and the task of either limiting (T2DM) (23) or increasing (T1DM) (24) sugar consumption are both factors that differ between people with and without DM, and have the potential to substantially affect oral health. Being able to measure relevant outcomes appropriately in these populations could help aid future research and interventions by improving our knowledge and understanding of oral health beliefs and behaviours within diabetic populations, and how education and other interventions may be directed to address any limitations.

Further, DM is experienced by a range of people from different backgrounds (25, 26). Access to appropriate tools to support the conduct of research in diverse samples is crucial for ensuring that the research findings are representative, generalisable, and can help reduce health inequalities. By collecting demographic information such as age and gender, we can verify the extent to which the participant group represents their target population. Additionally, this information can be used for further analyses within scale validation studies. For example, this data can be tested to measure how much variance is caused to scale responses by these demographic factors. Health-related demographic data is also important for this reason, particularly when focusing on health behaviours. Information such as dental visits, how often a person brushes their teeth or how long a person has been living with DM are all important factors that may contribute to variance within scale responses.

There is also a sound theoretical rationale underpinning the importance of measuring both beliefs and behaviours. Within health education, several theories have been described to explain the effective factors that lead to health behaviours. The Health Belief Model (HBM) (27) and the Theory of Planned Behaviour (28) are two widely recognised examples. The former focuses on how people interpret health threats and their subsequent actions (29, 30). It states that individuals are more likely to engage in health-promoting behaviours if they believe that they are vulnerable to a condition (perceived susceptibility), a condition could lead to serious consequences (perceived severity) and believe that being proactive would reduce their susceptibility to these consequences (perceived benefits). In addition to this, the

HBM also emphasises that for an individual to carry out health behaviours, they must have few perceived barriers such as financial or time-consuming obstacles (perceived barriers). They also must be exposed to actionable cues such as receiving health education or seeing others experience the same condition. Lastly, to have a greater chance of taking actionable measures, individuals have to possess self-efficacy and confidence in their ability to take action (31). The latter explains three key factors that shape people's intentions to carry out a behaviour: their attitude toward the behaviour, the social pressure they perceive (subjective norms) and their perceived control over performing the behaviour (32). Both frameworks are influenced by underlying behavioural, normative, accessibility and control beliefs. Personal beliefs play a crucial role in motivating individuals to act in managing health conditions such as DM, as these beliefs influence how seriously they perceive the illness, the benefits of actionable measures, and their confidence in managing their health effectively.

Beliefs about oral health, such as perceived susceptibility to gum disease, severity of consequences, and benefits of good oral care strongly influence whether individuals engage in protective behaviours. In people living with DM, these beliefs may be shaped by their understanding of the link between DM and oral health complications. Since DM increases risk for periodontal disease and delayed healing, beliefs about oral health take on added importance for motivating behaviours. Research has shown that oral health awareness significantly improves hygiene practises (11). Whereas misconceptions and lack of awareness can lead to inadequate oral hygiene practises such as infrequent brushing, flossing and dental visits (3, 33).

Therefore, the primary aim of this study was to develop and validate a new oral health scale to measure the personal oral health beliefs and behaviours of people living with DM. A secondary aim was to explore associations between the scale and health-related demographic factors.

Methods

Participants

Overall, three sets of sample group responses were collected; the first aimed for N = 300 to measure exploratory factor analysis (EFA), the second also aimed for N = 300 to measure confirmatory factor analysis (CFA) and the third (a subgroup of the second group) aimed for N = 30 to measure test-retest reliability. This met the commonly recommended sample size of a 10:1 ratio of respondents to scale items (34, 35).

The inclusion criteria were being over the age of 18 years, fluent in English and living in the UK, with either T1DM or T2DM. Exclusion criteria were being under 18 years old, not fluent in the English language and being diagnosed with prediabetes, gestational diabetes, or a systemic condition other than DM. These exclusions were necessary as the scale was specifically designed for populations with DM; therefore, oral health in people with other systemic conditions was beyond the scope of this study. Gestational diabetes is a type of DM that develops during pregnancy in women that do not already live with DM (36, 37). This type of DM resolves itself after childbirth, therefore this short duration means that it was also considered outside the scope of this study. Prediabetes was also deemed not applicable for this study as the term refers to elevated blood glucose levels that fall below the threshold of DM (38).

Participants were recruited (October 2024 - April 2025) using an online panel run through Qualtrics (www.qualtrics.com). Qualtrics is a leading online market research panel aggregator, widely used in psychological research including in previously published research from the group (39–41). The panel consisted of individuals who have signed up to take part in online studies in exchange for a small, fixed point-based reimbursement.

To ensure a demographically balanced sample, quota sampling was implemented using Qualtrics' built-in quota management feature. Quotas were set for DM type (T1DM (10%), T2DM (90%)) in alignment with UK DM prevalence

rates to ensure representativeness (42). Retest responses (third group) were set for 1–2 weeks after first completion of study.

Enforced screening criteria were put in place to ensure eligibility criteria was met. For example, 'What country do you currently reside in?' was asked with the response format, 'United Kingdom' or 'Other'. If 'Other' was selected, participants would be directed to the end of the survey. Similarly, postcode validation was included to ensure only those with UK postcodes would be able to continue with the study. Additionally, the response format for 'Which type of diabetes do you have?' was set to 'Type 1', 'Type 2', or 'I do not have diabetes' which, if selected, would direct participants to the end of the study.

Study Design

This study used an online cross-sectional survey design. Scale items were devised based on existing measures and insight from the literature in collaboration with dental professionals and experts within scale development. Relevant themes and constructs such as oral health beliefs, behaviours and experiences were identified from peer-reviewed studies (43, 44). The previously mentioned 7-item scale (DM-OH) (16) was used as an example of an oral health scale developed specifically for diabetic populations. As mentioned earlier, the wording of the items in this scale can lead people to the 'correct' answer which would increase chances of a higher score therefore, increasing chances of 'adequate oral health knowledge'. Draft items were generated to reflect these themes in a language appropriate and non-leading for the target group. The draft scale (**OHDM** - see below) was shared with a PPIE (Patient and Public Involvement and Engagement) group, consisting of people living with DM (both T1DM and T2DM). A group discussion was conducted with these individuals and researcher (RP) to ensure that items were understandable, relevant, and reflective of real-life experiences. The PPIE group confirmed during discussion that these requirements were met therefore no changes were made to the scale following this feedback.

Measures

Sociodemographic Questionnaire

Participants were asked demographic questions such as age, gender and ethnicity. The following health-related demographic questions were then asked, 'Which Type of Diabetes do you have?' so that comparisons can be made between T1DM and T2DM groups, 'How long have you been living with diabetes?' to see if duration of DM influences responses, 'Are you currently registered with a dentist?' and 'Is your dentist aware that you have diabetes?', both to see if there is an association between having a dentist and participants' oral health knowledge and awareness. Questions then relating to oral hygiene behaviours were given; 'How often do you brush your teeth?', 'Do you floss?' and 'Do you use mouthwash?'. These questions were asked to enable us to explore if oral health awareness correlates with oral health behaviours. Participants were then asked if they take any medication for their DM and if so, which one/s as medication can contribute to oral health complications. Lastly, they were asked if they have ever had professional dental treatment and if so, how often. Again, this was to look for any correlation between dental treatment and oral health measures.

Oral Health in Diabetes (OHDM) – 23-Item Scale

Participants were presented with the developed scale (see Table 1), which used a 'Yes' or 'No' response format.

Table 1
Participant demographics and comparative analysis between groups

Age (%)	(n = 680)	T1DM (n = 152)	T2DM (n = 467)	p
				< 0.001**
18–24	99 (14.6)	38 (25.0)	50 (10.7)	
25 to 34	177 (26.0)	50 (32.9)	112 (24.0)	
35 to 44	136 (20.0)	36 (23.7)	84 (18.0)	
45 to 54	101 (14.9)	20 (13.2)	74 (15.8)	
55 to 64	74 (10.9)	6 (3.9)	61 (13.1)	
65 or over	93 (13.7)	2 (1.3)	86 (18.4)	
Gender (%)				0.861
Male	327 (48.1)	71 (46.7)	224 (48.0)	
Female	353 (52.1)	81 (53.3)	243 (52.0)	
Ethnicity (%)				< 0.001**
White	504 (74.1)	99 (65.1)	372 (79.7)	
Ethnic minority	176 (25.9)	53 (34.9)	95 (20.3)	
IMD decile (mean (SD))	4.62 (2.70)	4.60 (2.52)	4.62 (2.76)	0.932
Diabetes Duration (%)				0.144
0–5 years	309 (45.4)	78 (51.3)	201 (43.0)	
6–10 years	194 (28.5)	42 (27.6)	130 (27.8)	
11–15 years	83 (12.2)	13 (8.6)	68 (14.6)	
16–20 years	43 (6.3)	6 (3.9)	33 (7.1)	
> 20 years	51 (7.5)	13 (8.6)	35 (7.5)	
Registered with dentist (%)	546 (80.3)	115 (75.7)	389 (83.3)	0.047*
Dentist is aware of DM diagnosis (%)	503 (92.1)	105 (91.3)	358 (92.0)	0.955
Dental Visits per year (%)				0.047*
Note. (p-value represents Chi squared test between T1DM and T2DM groups) *p < 0.05 **p < 0.001				

Age (%)	(n = 680)	T1DM (n = 152)	T2DM (n = 467)	p
				< 0.001**
1–2	363 (66.5)	68 (59.1)	274 (70.4)	
3–4	145 (26.6)	36 (31.3)	95 (24.4)	
> 4	38 (7.0)	11 (9.6)	20 (5.1)	
How often do you brush your teeth? (%)				0.029*
Once a day	129 (19.0)	20 (13.2)	103 (22.1)	
Twice a day	500 (73.5)	121 (79.6)	344 (73.7.2)	
More than 3 times a day	34 (5.0)	11 (7.2)	20 (4.3)	
Less than once a day	17 (2.5)	-	-	
Do you floss? (%)				0.607
No, I have never used floss	133 (19.6)	24 (15.8)	95 (20.3)	
No, I tried it, but I don't do it now	144 (21.2)	30 (19.7)	102 (21.8)	
Yes, once a day	201 (29.6)	50 (32.9)	139 (29.8)	
Yes, twice a day	89 (13.1)	18 (11.8)	57 (12.2)	
Yes, more than twice a day	21 (3.1)	6 (3.9)	15 (3.2)	
Yes, a few times a week	55 (8.1)	18 (11.8)	36 (7.7)	
Yes, a few times a month	37 (5.4)	6 (3.9)	23 (4.9)	
Do you use mouthwash? (%)				0.864
No, I have never used mouthwash	36 (5.3)	7 (4.6)	26 (5.)	
No, I tried it, but I don't do it now	118 (17.4)	26 (17.1)	87 (18.6)	
Yes, once a day	264 (38.8)	58 (38.2)	183 (39.2)	
Yes, twice a day	150 (22.1)	40 (26.3)	97 (20.8)	
Yes, more than twice a day	24 (3.5)	6 (3.9)	17 (3.6)	
Yes, a few times a week	54 (7.9)	9 (5.9)	34 (7.3)	
Yes, a few times a month	34 (5.0)	6 (3.9)	23 (4.9)	
Note. (p-value represents Chi squared test between T1DM and T2DM groups) *p < 0.05 **p < 0.001				

Age (%)	(n = 680)	T1DM (n = 152)	T2DM (n = 467)	p
				$\leq 0.001^{**}$
Do you take medication? (%)				0.001*
No, I do not take any medication	77(11.5)	23 (15.1)	53 (11.3)	
Yes, I take medication for my diabetes	378 (56.7)	89 (58.6)	264 (56.5)	
Yes, I take medication for oral health reasons	26 (3.9)	6 (3.9)	14 (3.0)	
Yes, I take medication for other reasons	62 (9.3)	6 (3.9)	47 (10.1)	
Yes, diabetes and oral health reasons	26 (3.9)	13 (8.6)	12 (2.6)	
Yes, diabetes and other	98 (14.7)	15 (9.9)	77 (16.5)	
Dental Treatment since being diagnosed with DM (%)				0.469
Fillings	102 (15.0)	31 (20.4)	67 (14.3)	
Root canal	23 (3.4)	7 (4.6)	16 (3.4)	
Teeth removed	64 (9.4)	16 (10.5)	46 (9.9)	
Scale and Polish	43 (6.3)	10 (6.6)	31 (6.6)	
No treatment	91 (13.4)	22 (13.8)	64 (13.7)	
Several treatments	329 (48.4)	67 (44.1)	243 (52.0)	
Treated for infection	13 (1.9)	-	-	
Dentures	10 (1.5)	-	-	
Cosmetic treatment	5 (0.7)	-	-	
Dental Treatment Frequency (%)				0.044*
Once	266 (39.1)	69 (45.4)	177 (37.9)	
Twice	222 (32.6)	51 (33.6)	143 (30.6)	
More than twice	192 (28.2)	32 (21.1)	147 (31.5)	
How would you assess the overall condition of your teeth and gums? (%)				0.744
Very poor	40 (5.9)	7 (4.6)	26 (5.6)	
Poor	108 (15.9)	21 (13.8)	78 (16.7)	
Acceptable	320 (47.1)	71 (46.7)	224 (48.0)	
Note. (p-value represents Chi squared test between T1DM and T2DM groups) *p < 0.05 **p < 0.001				

Age (%)	(n = 680)	T1DM (n = 152)	T2DM (n = 467)	p
				< 0.001**
Good	168 (24.7)	41 (27.0)	111 (23.8)	
Very good	44 (6.5)	12 (7.9)	28 (6.0)	
Note. (p-value represents Chi squared test between T1DM and T2DM groups) *p < 0.05 **p < 0.001				

{Table 1 SHOULD BE INSERTED HERE}

Procedure

The study was accessible to participants via either a link or a QR code. A participant information sheet and consent form were both provided as well as a debrief form, before the end of the study. Ethical approval was obtained from the University of Liverpool’s Institute of Population Health Research Ethics Committee in August 2024 (reference: 13743). The study protocol and analysis strategy were pre-registered on the Open Science Framework before data collection commenced (<https://osf.io/9guwq/>).

Data Analysis

Data were analysed with R version 4.4.1, using the ‘lavaan’ and ‘psych’ packages for scale validation. For demographic analyses, ‘Hmisc’, ‘PerformanceAnalytics’ and ‘car’ packaged were used.

Data Preparation

Prior to analyses, responses were coded as 0 (‘No’) and 1 (‘Yes’). No items required reverse scoring. Sampling adequacy was checked using the Kaiser-Meyer-Olkin (KMO) statistic and Bartlett’s Test for Sphericity was used to assess whether correlations between variables were large enough for factor analysis ($p < 0.001$).

Exploratory Factor Analysis (EFA)

Prior to conducting the EFA, a Parallel analysis was performed to determine the number of factors in the data. The EFA was run with an oblique rotation as factors were expected to correlate with each other. This analysis was carried out on the tetrachoric correlation matrix rather than the raw data, as appropriate for binary measures. Loadings of ≥ 0.5 have 25% of variance in the factor, suggesting strong association to their respective factor. Therefore, items with factor loadings < 0.5 were discarded, as were those that cross-loaded, namely had two or more factor loadings of > 0.3 .

Confirmatory Factor Analysis (CFA)

Using the structure identified in the EFA, the CFA was carried out on the data from the second group using a weighted least square mean and variance adjusted estimator (as the data was binary). The fit of the model was assessed using the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), the Root Mean Square of Approximation (RMSEA), and the Standardised Root Mean Square Residual (SRMR). The values for the CFI and TLI were considered good if above 0.95 and acceptable if above 0.90. RMSEA demonstrated good fit for the model if < 0.06 and a moderate but acceptable fit if the score lay between 0.06 and 0.08. SRMR indicated a good fit if the score was < 0.08 (45).

Internal Reliability

Internal reliability testing was carried out on the second group of participants, producing McDonald’s omega total for the subscales and Omega hierarchical to ascertain reliable variance across the full scale. The latter values allowed us to

establish whether a total score of the scale can be reliably used, or whether scoring of individual subscales would be more appropriate. An acceptable value for both measures was > 0.7 (46).

Convergent validity

Correlations between health-related demographic data and subscale scores were used to assess convergent validity of the full dataset.

Test-retest reliability

In addition to the above, participants from the second group were contacted two weeks after study completion to ask if they were willing to take part in the study again. This data was required to assess the test-retest reliability of the scale, using an intraclass correlation (ICC). ICC's of 0.6 or above were considered to show good test-retest reliability (47).

Results

Two datasets of participant responses were collected: the first ($n = 328$) dataset was used to conduct exploratory factor analysis (EFA), the second ($n = 352$) was used for confirmatory factor analysis (CFA). A third, a subset of participants from the second group, took part in this study again ($n = 37$) to measure test-retest reliability. Table 2 shows the demographic characteristics of all participants who completed this study ($n = 680$) as well as a comparative analysis between groups with T1DM and T2DM. Due to low frequency comparative analyses reported groups, $n = 61$ participants were removed for the gender, tooth brushing, medication and dental treatment analysis. Also due to low frequency groups, ethnicity was collapsed to White vs. people from ethnic minority backgrounds. Of all the participants 26.0% were between the ages of 25 to 34, 52.1% were female, 74.1% of White ethnicity and most were diagnosed with DM in the previous 0–5 years (45.4%). Overall, the majority (75%) of participants had a diagnosis of T2DM ($n = 467$, 52% female, 79.7% White ethnicity) which was less than the quota set (90%).

Table 2
OHDM item factor loadings

Item		Factor 1	Factor 2
		Oral Health Beliefs	Oral Health Complications
1	Has your dentist ever asked you about your diabetes when discussing your oral health?	0.27	0.22
2	When eating, do you control your sugar intake to look after your diabetes?	0.43	-0.3
3	When eating, do you control your sugar intake to look after your teeth?	0.43	-0.31
4	Do you think that having diabetes has affected your oral health negatively?	0.17	0.56
5	Is your oral health a main priority for your overall health?	0.29	-0.05
6	Do your gums bleed whilst brushing your teeth?	-0.07	0.68
7	Do you think diabetes can cause/increase risk of bleeding gums?	0.57	-0.08
8	Do you have tooth decay? (dental caries/'holes in teeth')	0	0.67
9	Do you think diabetes can cause/increase risk of tooth decay? (dental caries/'holes in teeth')	0.71	0
10	Do you have dry mouth? (xerostomia)	0.09	0.5
11	Do you think diabetes can cause/increase risk of dry mouth? (xerostomia)	0.67	0
12	Do you think the medication you take can cause/increase risk of dry mouth? (xerostomia)	0.45	0.22
13	Have you experienced bad breath? (halitosis)	0.11	0.51
14	Do you think diabetes can cause/increase risk of bad breath? (halitosis)	0.54	0.15
15	Have you had an infection in the mouth since being diagnosed with diabetes that has resulted in you taking prescribed antibiotics?	-0.04	0.71
16	Do you think diabetes can cause/increase risk of an infection in the mouth?	0.72	-0.02
17	Have you noticed any mouth pain since being diagnosed with diabetes?	0.11	0.65
18	Do you think diabetes can cause/increase mouth pain?	0.6	0.2
19	Have you noticed any loose teeth since being diagnosed with diabetes?	0.07	0.56
20	Do you think diabetes can cause/increase risk of loose teeth?	0.69	0.19
21	Do you think that medication you take can cause/increase risk of oral complications?	0.55	0.14
22	Do you think that poor diabetes management can cause/increase risk of oral problems?	0.69	-0.22

Note. Factor loadings highlighted in bold indicate onto which factor the respective item loaded and item factor loadings that were removed are shown in italics

Item		Factor 1	Factor 2
		Oral Health Beliefs	Oral Health Complications
23	Do you think gum disease can have a negative effect on your diabetes management (blood sugar levels)?	0.68	0.03
<i>Note. Factor loadings highlighted in bold indicate onto which factor the respective item loaded and item factor loadings that were removed are shown in italics</i>			

{Table 2 SHOULD BE INSERTED HERE}

Data Preparation

The KMO statistic exceeded the acceptable level of 0.7 (KMO = 0.81), and Bartlett's Test for Sphericity indicated that correlations between items were large enough for factor analysis ($X^2(253) = 1568.22; p < 0.001$).

Exploratory Factor Analysis (EFA)

Parallel analysis deemed a two-factor model to be the best fit. Applying both two- and three-factor solutions to the EFA revealed a two-factor solution to be the most parsimonious, based on the factor loadings. Items with factor loadings below < 0.5 on both factors were disregarded (five items), leaving 18 items remaining (see Table 2, deleted items can be seen in italics). All other items loaded onto one factor, without any cross-loading present. Factor 1 was made up of 10 items and named 'Oral Health Beliefs (**OHB**)' as it comprised of items relating to 'Do you think diabetes can cause/increase risk of X', X being an oral health complication. Factor 2 was made up of eight items and named 'Oral Health Complications (**OHC**)' as it comprised of items asking if participants had experienced an oral health complication.

{Table 2 SHOULD BE INSERTED HERE}

Confirmatory Factor Analysis (CFA)

CFA indicated a good fit of the model to the data (CFI = 0.995; TLI = 0.995; RMSEA = 0.017; SRMR = 0.073); $X^2(134) = 148.389, p = 0.187$), without the need for additional modification indices to be used. Figure 1 shows the scale factor model with standardised factor loadings.

Internal Reliability

The McDonald's Omega hierarchical value for the full scale was below the acceptable value of 0.7 ($w_h = 0.65$), suggesting that there is not reliable variance in responses produced by a common factor across all sections. Reliability statistics were produced for each subscale and both achieved acceptable estimates (**OHB** $w_t = 0.91$; **OHC** $w_t = 0.84$). Taken together, this suggests that responses are reliable across individual subscales, but a reliable total scale score cannot be produced.

Convergent Validity

Table 3 shows the Pearson correlation coefficients among the demographic variables and subscale scores of respondents. Higher scores on the **OHB** subscale indicate stronger beliefs in the link between oral health and DM. Therefore, it was expected that all demographic variables would be positively correlated with **OHB** scores. However, only visits to the dentist had a significant correlation with **OHB** subscale scores, showing a positive correlation ($r = .12, p < .01$), indicating that the more dental visits, the greater the beliefs/awareness of oral health complications associated

with DM. Higher scores on the **OHC** subscale show greater experience of oral health complications. It was predicted that age and DM duration would be positively correlated with **OHC** scores whereas IMD decile, dental visits and teeth brushing frequency would be negatively correlated. Unexpectedly, age was significantly negatively correlated with **OHC** subscale scores ($r = -.23, p < .01$), indicating that the older participants reported experiencing fewer oral health complications than the younger participants. Also significantly correlated with **OHC** scores were dental visits, highlighting that more dental visits are linked to more oral health complications.

Table 3
Pearson correlation coefficients (r)

Age	OHB	OHC
	-0.01	-0.23*
IMD Decile	0.05	-0.08
Diabetes duration	0.04	-0.02
Dental visits	0.12*	0.28*
Brushing teeth frequency	0.07	0.08

Note. * $p < 0.01$

Test-Retest Reliability

Mean scores for the initial test and retest were calculated ($n = 37$), and test-retest reliability was found to be good for both the **OHB** subscale (ICC = 0.81) and the **OHC** subscale (ICC = 0.83) as well as for the overall scale (ICC = 0.76).

Demographic Analyses

Multiple Welch t-tests were conducted to examine differences in subscale scores across specific demographic groups (See Table 4). To account for multiple comparisons and control the family-wise error rate, a Bonferroni correction was applied, resulting in a corrected significance level of $p < 0.006$. No significant differences in subscale scores were found between gender (male and female), ethnicity (white and ethnic minority backgrounds), DM type (T1DM and T2DM), nor registration with a dentist (registered and not registered).

Table 4
Multiple Welch t-tests

Variables		OHB	t (df)	p	OHC	t (df)	p
Gender	Male	0.60	-1.34 (614.61)	0.181	0.39	-0.54 (626.41)	0.588
	Female	0.63			0.41		
Ethnicity	White	0.62	0.85 (250.65)	0.397	0.39	-1.09 (255.35)	0.278
	Ethnic minority	0.60			0.42		
DM Type	T1DM	0.62	0.060 (292.78)	0.952	0.44	1.91 (261.46)	0.0572
	T2DM	0.62			0.39		
Registered with a dentist?	No	0.57	-2.25 (194.43)	0.026	0.43	1.33 (199.94)	0.185
	Yes	0.63			0.39		

Note. OHB and OHC: mean subscale scores

Discussion

The current study developed and validated a scale designed to measure oral health beliefs and complications among those living with DM (the **OHDM** scale). EFA revealed a two-factor structure. CFA demonstrated a good model fit for this structure, comprising OH Beliefs (**OHB**) and OH Complications (**OHC**). Additionally, the scale showed good test–retest reliability over a two-week interval.

Items in factor 1 referred to oral health beliefs and items in factor 2 referred to oral health complications experienced. Mean scores on each subscale did not differ between demographic groups, including gender, DM type, and ethnicity. The first subscale reflects people's knowledge of the DM-oral health link as it measures their perceived beliefs of oral health complications being associated with DM. The second subscale captures experiences of the oral health complications referred to within the first factor, this highlights the consequences of oral disease from poor hygiene practise and the increased risk experienced by those with DM. Rather than reflecting the anticipated behavioural tendencies, items loading onto the second factor were more indicative of the adverse effects associated with poor oral health. These included complications such as tooth decay, bad breath and oral infection. As such, this factor was reinterpreted as representing 'Oral Health Complications', which appears to be a distinct and meaningful dimension within this context. While not originally conceptualised as a primary construct, complications emerged as an empirically supported and theoretically relevant domain as they reflect the lived reality of managing a condition. Research has suggested integrating both beliefs and oral health status within this field of research (48). The final scale therefore comprises two subscales: **OHB** and **OHC**. Together, these factors capture both the belief system (what people with DM think and believe about their increased risk of oral disease) and the oral consequences they currently experience. This distinction is important because beliefs can drive behaviours, and personal experiences can reinforce or sometimes challenge those beliefs. This distinction underscores the multifaceted nature of DM and oral health, where both beliefs and lived experiences have the ability to shape behaviours, consistent with constructs in established health behaviour theories (27, 28). This dual-factor model aligns with these health behaviour theories that separate cognitive beliefs from risk perceptions or health status. Despite the absence of a behavioural subscale, the observed demographic factors reflect certain oral health behaviours such as frequency of tooth brushing. The analysis of these responses, in conjunction with the subscale scores, helps to reflect and capture the original intention of the scale.

The scale was developed with reference to Yuen et al., (49) whose work provided a conceptual foundation for the present study. The resulting **OHDM** scale demonstrates significant improvements compared to those discussed in the limitations section of this paper. Comprehensive reliability and validity assessments yielded good to excellent results, supporting the robustness of the instrument. The item wording was carefully crafted to be neutral and non-leading, thereby minimising response bias. An initial draft of the scale was reviewed by a PPIE group, as well as academic experts, before being administered to the study sample. Importantly, the scale was specifically developed for people living with DM, ensuring that the items are relevant and appropriately targeted. These enhancements have enabled the scale to effectively meet the objectives of this study and address an existing gap in oral health research related to DM.

A secondary aim of this study was to examine how demographic factors may influence responses to the scale, providing insight into potential variations in oral health beliefs and experiences across different population groups and behaviours, as well as providing convergent validity outcomes. While some measures showed strong correlations in the expected direction, others did not support the hypothesised relationships. Notably, dental visits and **OHB** subscale scores were positively correlated, supporting convergent validity. This reaffirms the idea that visiting a dentist not only supports a person through clinical care but also reinforces oral health knowledge and corrects misconceptions (50). In addition, dental visits and **OHC** subscale scores correlated. This outcome lends itself to more than one interpretation. One such perspective is that those experiencing multiple oral health complications require multiple dental visits in order to receive the most adequate treatment. Studies have demonstrated that individuals are more likely to visit the dentist after

experiencing symptoms such as tooth pain or infection (51). This shows a reactive behaviour that is problem-driven, rather than a preventative behaviour. The exhibited positive correlation could therefore reflect delayed oral care and therefore increased dental visits as a response to dental problems. On the other hand, one could expect that higher amounts of dental visits would correlate with lower **OHC** subscale scores as dental visits can aid with preventative treatment and therefore, improved oral health outcomes (52, 53). A third explanation could be that a higher prevalence of dental visits increases the likelihood of identifying oral complications. That is, visiting the dentist more often brings attention to oral complications that may have been missed without a clinician's expertise. Future research employing this scale could investigate this phenomenon further to help distinguish between these possible explanations.

Contrary to expectations, age and **OHC** subscale scores were negatively correlated. This finding indicates that those in the older age groups reported fewer experiences of oral complications than those in the younger age groups. This contradicts previous research which shows a positive correlation between age and oral disease (54, 55). An explanation for this finding could be the increased prevalence of edentulism (complete or partial loss of natural teeth) in older age groups (56). Therefore, the chances of currently experiencing the oral health complications referred to in the scale could be smaller than for dentulous participants as the presence of teeth is needed for the possibility of complications such as dental disease or loose teeth. It could be beneficial for future studies to include a screening question regarding the presence of natural teeth so that further analysis can be conducted to help explain this outcome. This finding may also reflect a heightened interest in dental aesthetics among younger audiences, influenced by social media, which has increasingly driven them to pursue unnecessary cosmetic procedures (57). Some of which have the potential to cause harm, such as veneers which can affect gingival health and cause bleeding (58). Future research may seek to collect information regarding aesthetic dental treatments.

The development of this scale presents an important development in the measurement of oral health beliefs and complications within diabetic populations. In the future, there is potential for this scale to be used in research studies or in healthcare settings to guide the development of appropriate interventions, educational initiatives, and resource allocation, as well as to evaluate their impact effectively.

Several limitations of this study should be acknowledged. First, recruitment via Qualtrics panels may introduce financial bias, as participants received compensation for their participation (e.g., points redeemable for cash or retail vouchers), which could influence their responses or motivation. Second, although demographic quotas were met, the sample lacked sufficient ethnic diversity, limiting the generalisability of the findings. In particular, future research should aim to include participants from a broader range of backgrounds, especially those groups at higher risk for developing DM such as people living with obesity (59) and those from minority groups (60) to ensure the scale's applicability across diverse populations.

Conclusions

In conclusion, this study introduces a valid and reliable tool to assess oral health beliefs and complications in diabetic populations. By specifically addressing oral health complications associated with DM, this scale fills a critical gap in this multidisciplinary field and raises awareness of the need for continued research. Future studies should focus on evaluating divergent validity to ensure the scale does not correlate highly with unrelated concepts, perhaps by measuring this scale against DMFT (decayed, missing and filled teeth) scores. Furthermore, validating the scale across diverse groups, including individuals with gestational diabetes and adolescents living with DM would demonstrate the consistency of the scale's structure across groups. Ultimately, this tool holds significant potential for enhancing educational resources and targeted interventions pertinent to DM management.

Abbreviations

CFA Confirmatory Factor Analysis

CFI Comparative Fit Index

DM Diabetes Mellitus

DMFT Decayed Missing Filled Teeth

EFA Exploratory Factor Analysis

GP General Practitioner

HBM Health Belief Model

ICC Intra-class Correlation

IMD Index of Multiple Deprivation

KMO Kaiser-Meyer-Olkin (statistic)

OHB Oral Health Beliefs

OHC Oral Health Complications

OHDM Oral Health in Diabetes Scale

OHIP-14 Oral Health Impact Profile Scale

PPIE Patient and Public Involvement and Engagement

RMSEA Root Mean Square of Approximation

SD Standard Deviation

SRMR Standardised Root Mean Square Residual

TLI Tucker-Lewis Index

T1DM Type 1 Diabetes Mellitus

T2DM Type 2 Diabetes Mellitus

UK United Kingdom

US United States

yrs Years

Declarations

Ethics approval and consent to participate

Ethical approval was gained for the study from University of Liverpool's Institute of Population Health Research Ethics Committee (reference: 13743). Informed consent from all participants was obtained prior to participation in the study.

The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and its subsequent amendments.

Consent for publication

Not applicable.

Competing Interests

The authors declare that they have no competing interests.

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Author Contribution

RP, EB and PC conceptualised the study. RP was responsible for carrying out the study, developing the scale, recruitment, data analysis, data interpretation and writing the manuscript. EB, GK, NF and PC contributed towards the development of the scale. EB and PC also provided feedback on draft copies of the manuscript. PC contributed extensively to the statistical analysis. All authors read and approved the final manuscript.

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Data Availability

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request. The materials generated in the current study are available in the Open Science Framework repository (<https://osf.io/9guwq/>).

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Figures



Figure 1

OHDM factor model with standardised factor loadings (single-headed arrows) and covariance (double headed arrow)